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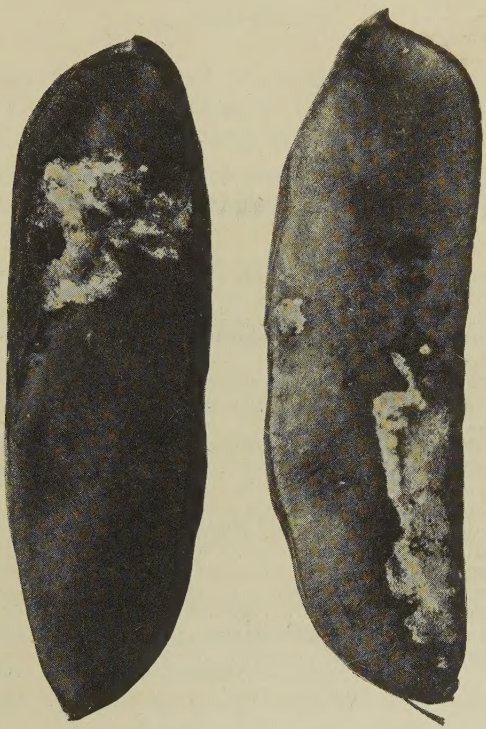
Combating Diseases of Vegetables

Charles Chupp



Downy mildew on lima beans

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SEASONAL PROGRAM FOR COMBATING DISEASES OF VEGETABLES

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COMBATING DISEASES OF VEGETABLES

CHARLES CHUPP

This bulletin has been prepared in response to constant requests for short descriptions of vegetable-disease control measures. It also is meant to show the fallacy of the idea that seed treatment and spraying are the only means by which plant parasites can be combated. Many other methods that aid in growing clean crops are recommended.

ROTATION OF CROPS

A large proportion of the organisms that cause plant diseases live over winter in the field, either in the old infected plants or directly in the soil. Even tho some of these organisms are so long lived that a rotation of twenty years in length would not free the soil entirely of their presence, there are others that die in one to five years, or are so greatly reduced in numbers or in virulence that rotations of this length are of great value.

In following one crop with another, it should be borne in mind that two or more crops may have the same disease, and, therefore, such crops should not come near together in the rotation. For instance, the wilt fungus that destroys so many plantings of Black Beauty eggplants, may also be present on potatoes, raspberries, and tomatoes; the diseases of cabbage are similar to those of cauliflower, brussels sprouts, and other cruciferous crops; and the Sclerotinia rot of carrots is also destructive on cabbage and celery.

Among other parasites that live in the soil or the plant refuse are the ones that cause black rot, blackleg, clubroot, and yellows of cabbage; blights of celery; root rots of beans; smut of sweet corn; root knot of many greenhouse crops; drop and bottom rot of lettuce; smut, neck rot, and pink rots of onions; root rots of peas; wilt of tomatoes; and damping off of seedlings. The organisms that cause black rot and blackleg of cabbage, the blights of celery, and the root rots of peas, are much reduced, if not entirely destroyed, by a three-year rotation. The clubroot of cabbage and the dry root rot of beans need at least six years for much decrease in the amount of injury, while the remaining diseases mentioned may be influenced by long rotations, but in those cases this means of control can be practiced only in connection with other methods.

ERADICATION OF WEEDS

It is noticeable that the farm on which the weeds are kept under control has fewer vegetable diseases of a certain type than do other farms where every uncultivated spot, especially along the fences, is permitted to grow up into a luxuriant mass of weeds. This is true especially since mosaic has become so destructive on cucurbits and tomatoes. The virus that causes the mosaic of cucumbers and muskmelons winters over in such perennial plants as milkweed, pokeweed, ground cherry, and catnip, and in the seed of the wild or bur cucumber; the tomato mosaic is transmitted from ground cherries, horse nettles, Jimsonweed, nightshade, bittersweet, and matrimony vine; the clubroot of cabbage and cauliflower may continue to live on wild mustard and other weed crucifers; downy mildew of lettuce thrives on wild lettuce; and the late blight of tomatoes is found also on the horse-nettle plant. When these weeds are eradicated within a radius of at least one-fourth mile from the field to be protected, the cultivated plants growing there are much less likely to become diseased than if these weeds are not removed.

DRAINAGE

Most fungous or bacterial parasites thrive best where moisture is plentiful. Downy mildew of onions, celery blights, bean anthracnose, and other leaf blights and mildews, are more prevalent in the low spots of the field than elsewhere. This may be due partly to the lack of air drainage, but much of it results from too wet a soil. The obvious remedy is that of drainage, either by means of tile or open ditches. Not only does drainage remove the excess water, but it also tends to make the moisture supply uniform thruout the growing season, and thus helps to reduce the amount of such diseases as tipburn of cabbage and blossom-end rot of tomatoes.

APPLICATIONS OF FERTILIZERS AND SOIL AMENDMENTS

The application of a reasonable amount of a balanced fertilizer is highly desirable for a good growth of vegetables, but inadequate or excessive fertilization may increase susceptibility to disease. Tipburn of lettuce is increased by the use of fertilizers high in potash. Whiptail of cauliflower and malnutrition of cabbage and of spinach may be induced by using too large amounts of commercial fertilizer, particularly if it is not well balanced, or if it causes the soil to become acid. The Macrosporium leafspot and the tipburn of cabbage become more severe in the presence of certain fertilizer combinations; an excess of nitrogen apparently being an

important factor in this increase of the disease. Streak of tomato may be common in greenhouses where there has been a heavy application of barnyard manure. It has been found that side-dressing the plants with acid phosphate and potash (with the ratio of 12 parts of phosphoric acid to one of potash, 3 ounces to a plant) has proved effective in reducing the injury from this disease.

Alkaline or acid soils may play an important part in increasing or decreasing the amount of disease injury. The case that is cited so often is the application of lime for the control of clubroot of cabbage and other crucifers. If enough lime is added so that the reaction of the soil is plainly above the neutral point, there will be little or no clubroot; but, if the soil is permitted to become acid, clubroot may be destructive. Cauliflower will not stand much soil acidity, and malnutrition, known as whiptail, is soon evident on plants grown in such an unfavorable environment. The application of lime tends to reduce the amount of such injury. On the other hand, lime or hardwood ashes added to the soil may accelerate the spread of potato scab.

Acidity is not the only condition in the soil that needs correcting. Certain muck soils in the State have proved unproductive until copper sulfate, or some other form of copper, is added. Rabbit-ear of lettuce is an excellent example of an abnormal plant condition which may be corrected by adding copper to the soil.

SELECTION OR PURCHASE OF SEED

Whenever it is possible to grow vegetable seed of a good quality and at a reasonable cost on the home farm, it is better to do so than to buy that which may be diseased, for it is definitely proved that the organisms that cause many of the common vegetable diseases are carried in or on the seed. If the seed is grown on the farm, the grower knows what diseases may be present and accordingly can take precautions to control them. On the other hand, there are many kinds of seed which the average farmer can not produce profitably.

If seeds are saved from cucumbers, melons, eggplants, tomatoes, squash, pumpkins, and peppers, the first requisite is perfectly healthy fruit. If spots, rots, or blemishes are present, the fruit should not be used as a source of seed. If the seed is removed from the fruit in such a way that there is a possibility of surface contamination, the whole fruit should be dipped into corrosive sublimate (1-1000) for five or ten minutes, before it is cut open.

Sometimes it is possible to obtain seed from a State or a county where the diseases do not occur, or at least, are rare. Sweet-corn seed grown in the South may be infected heavily with the bacterium that causes Stewart's

disease, but it seldom is found in up-state New York and farther north. Pea seed grown in the Eastern and Central States may be seriously infected with Ascochyta which causes pea blight, while seed grown in the far Northwest seems uniformly free from the trouble. In the Middle and Southern States eggplants have a destructive Phomopsis blight, but in up-state New York and farther north the seed is almost sure to be free from this organism. Roots of rhubarb produced in southern Pennsylvania and farther south may have a Phytophthora rot, which rarely, if ever, occurs under New York State conditions. If seed beans are inspected and certified, it is possible to know the amount of mosaic present in the seed, and to avoid that which shows a high percentage of infection. During certain years when the Grand Rapids disease of tomato, or tomato canker, is severe in some sections of the State, it is well to make sure that the seed for the next crop comes from healthy fields. Still other cases might be mentioned to make it evident that the source of seed may be an extremely important consideration to the grower.

RESISTANT VARIETIES OR STRAINS

The work of plant breeding in connection with disease resistance has only just begun, but even now there are many varieties or strains of vegetables resistant to some of the most serious diseases. A few of the more resistant varieties or strains are listed on page 7.

Still other varieties of vegetables are constantly being bred, so that finally it is the hope that all of the most destructive diseases can be controlled in this manner.

SEED TREATMENT

Many vegetable seeds are so delicate that they will not withstand long enough or severe enough treatment to kill the parasite within the seed coat or on the surface. But where treating can be done successfully, it is a quick and a relatively easy way of controlling the organism. Unlike spraying, the application needs to be made only once, and then can be forgotten for the remainder of the season. The soil may be so heavily infested that seed treatment is of little value. For example, it seldom pays to treat celery seed for late blight or cabbage seed for Macrosporium blight. Some instances where it has proved profitable to disinfect contaminated seed are given in the tabulation on page 8.

In treating seeds with corrosive sublimate, they are tied loosely in a cheesecloth bag and are placed in the solution for the required length of time. Too many seeds in one bag will not permit the liquid to reach those at the center. To make sure that the air is not replacing the liquid, the bags should be prodded repeatedly with a stick. When the seeds

Vegetable	The more resistant varieties or strains	Disease
Asparagus	Mary Washington, Martha Washington	Rust
Bean	Perry Marrow, Wells' Red Kidney, White Imperial, Nova Scotia Marrow, Michigan Robust Pea, Yellow Eye	Anthracnose
Bean	Michigan Robust Pea, Red Marrow, White Marrow, Long Pod, Keeney Rustless, German Black Wax, Refugee Wax, Michigan White Wax, Red Valentine, Prolific Black Wax, Scarlet Flageolet	Mosaic
Bean (Listed as resistant under Virginia conditions)	Marblehead, Tennessee Wonder, Brockton, Indian Chief, Everbearing, Mont d'Or, Hodson Green Pod, Refugee, Early Mohawk, May Queen, Improved Goddard, Low's Champion, Early Refugee, Mexican Red, Golden Eye, Detroit, Hodson Wax, New Pearl, Wardwell, Challenge, Crystal White, Flageolet, Webber, California, White Kidney, Wells' Red Kidney, Yellow Eye, Dwarf Horticultural, French's Horticultural	Rust
Bean	Michigan Robust Pea, Perry Marrow, Yellow Eye, Scotia	Bacterial blight
Celery	Michigan selection of Golden Self Blanching, all green varieties	Yellows
Cabbage	Wisconsin Hollander, All Head Select, Globe, Marion Market, Iacope, other selected strains	Yellows
Corn (sweet)	Evergreen, Country Gentleman, and other late varieties	Stewart's bacterial disease
Cucumber	Chinese Long (not a commercial variety)	Mosaic
Lettuce	Iceberg, Big Boston, Hanson	Downy mildew
Onion	Red or yellow varieties	Smudge
Peas	Horal, Green Admiral, Yellow Admiral, Rogers K, Pedigreed Extra Early, Rice's 350	Root rot
Spinach	Virginia Savoy	Blight
Tomato	Louisiana Red, Louisiana Pink, Marvel, Norton, Columbia, Arlington, Marvana, Marglobe, Kanora	Wilt

have been in the solution the required length of time, they are removed and at once are rinsed thoroly in running water, after which they may be dried or planted while still partly wet.

The hot-water method is more complicated and, if the seed is old or otherwise weakened, this treatment may cause serious injury. Consequently it should be used only when clean seed cannot be obtained otherwise. It is well to have the hot water in a large container like a wash boiler or a tub. There should be another container with boiling water and one with cold, so that when the temperature varies from that which is recommended, it can be returned to the exact degree by putting in either hot or cold water, as may be necessary. The seeds are tied loosely in cheesecloth bags and are immersed in the hot water. The bags should be stirred repeatedly to get out all the air. When the seeds have been in the water the required length of time, the bags are removed quickly and thrown into cold water, so that the seeds will not be subjected to a high temperature longer than is recommended. When the seeds are cool, they may be dried or planted while still wet.

When roots are planted instead of seeds, it has proved beneficial to disinfect them also, as in the case of bacterial root rot of horse-radish, where the treatment is fifteen minutes in corrosive sublimate (1-1000), and of Phytophthora rot of rhubarb, where the treatment is thirty minutes in a similar solution.

Vegetable	Method of treatment	Disease
Sweet corn.....	0.5 per cent organic mercury, 1½ hours	Stalk, root, and ear rot, seedling blight
Cabbage (other crucifers)	1–1000 corrosive sublimate, 20 minutes	Peppery leaf spot, black rot
Cabbage (other crucifers)	Hot water, 122° F., 25 minutes....	Blackleg
Cucumber (other cucurbits)	1–1000 corrosive sublimate, 5 minutes	Anthracnose, angular leaf spot, scab
Eggplant.....	1–1000 corrosive sublimate, 10 minutes	Phomopsis blight
Peppers.....	1–80 copper sulfate solution, 5 minutes, then dust with hydrated lime	Anthracnose, bacterial spot, Cercospora leaf spot, black spot
Tomato.....	1–3000 corrosive sublimate, 5 minutes	Bacterial spot

TIME OF PLANTING

The diseases on a few vegetables are influenced by the time the seed is sown, or rather by the time the plants reach a stage of development when they are most susceptible. Early celery in New Jersey is injured only slightly by the bacterial soft rot, but much of that which is maturing during July or August may be lost by this rot. In New York the Boston head lettuce may be grown early or late, but that maturing in midsummer is liable to severe injury from tipburn. One type of bacterial blight of beans can be reduced greatly by planting the crop as late as is possible for maturity. The difficulty lies in the fact that another type of the blight is not controlled by the same planting, and the grower has no way of determining which type is affecting his plants.

SEEDBED TREATMENT AND SOIL STERILIZATION

In growing delicate plants like most vegetable seedlings, a number of precautions are necessary to obtain thrifty growth. One of the first requisites is a well-drained soil that will hold moisture without being too heavy. The importance of water in the seedbed soil cannot be overemphasized, for nearly all the organisms that cause damping off are influenced greatly by moisture. For this reason, a high-roofed greenhouse in which the air circulates freely is much more desirable than a sash hotbed, where the vapor from the soil and the foliage is confined near the plants. If the hotbed is used, it should be opened during warm sunshiny days, and closed carefully when there is any rain. In addition, the topsoil should be stirred frequently to aid its drying, or loose sand or another quick-drying substance should be sprinkled over the surface. The plants, too, should be spaced far enough apart to permit the surface of the ground to dry quickly.

When water is applied to the seedbed, it is preferable to put on a large amount at long intervals rather than small amounts frequently. The watering should be done in the morning and on sunshiny days if possible.

If all the precautions are taken regarding wet soil and humid air, there is little or no danger from damping off, even tho the fungous parasites are present. But there are always a number of growers who must raise their seedlings in hotbeds or in low, poorly ventilated greenhouses. They may also have to use heavy soils. For this reason it is well to know the few remedies that are suggested for the control of damping off, or blackleg as some growers like to name it.

Since there is so much danger of recontamination when the soil is sterilized, the average grower has been more successful in using a chemical disinfectant that will guard the sprout until it gets above the ground.

An additional amount of the fungicide may then be applied to protect the young plants until they are ready to transplant. The fungicides used are copper carbonate, corrosive sublimate, and commercial organic-mercury compounds. One pound of copper carbonate is mixed with 25 gallons of water. One ounce of powdered corrosive sublimate is dissolved in a little hot water and then added to 15 gallons of water (or 1 tablet in a quart of water) and freshly applied. The organic-mercury compounds are diluted according to the directions on the cans. One pint of any one of the solutions just mentioned is sprinkled over each square foot of soil after the seed is sown. The whole bed is then wet down with water.

After the plants are up, treatments may be made with the same strength of copper carbonate or corrosive sublimate. One pint is used for approximately five feet of row. The copper carbonate is less liable to cause injury and should be applied on the more delicate plants as lettuce, celery, and melons even tho it is not so good a fungicide as corrosive sublimate.

The corrosive sublimate is applied to cabbage, cauliflower, radish, and brussels sprouts once a week as long as there is danger of damping off or of wire stem. It should never be poured directly on the leaves, but should be applied in such a manner that it will wet the soil about the base of the plant. A sprinkling can may be used for making the application if a V-shaped opening is cut into a cork, and the cork is inserted in the sprout of the can. The opening should be just large enough to permit the required amount of liquid to flow out.

In some cases damping off may be controlled by changing the soil in the greenhouses, the new soil being procured from a part of the farm where vegetables have not been grown recently. The only objection is that the fungous parasites may be present even in this new soil and may cause damping off. The changing of the soil, however, is effective against nematodes, or root knot, and certain specific diseases of vegetables.

Where the soil cannot be changed, and where a disease such as drop of lettuce is present, it is well to sterilize the soil. This may be done by the application of either formaldehyde or steam.

If commercial formaldehyde is used, it is diluted, 1 gallon in 50 to 100 gallons of water, depending upon the severity of the disease to be combated. The solution is applied with a sprinkling can or a hose as the soil is being spaded or plowed. About 1 gallon is necessary for each square foot to be treated. After the fungicide is applied, the treatment is made more effective by covering the area with matting or boards for a day, altho this is not absolutely necessary. As soon as the soil is dry enough, it is stirred so that the remaining fumes will escape and

the drying will be facilitated. An interval of at least ten days should elapse after the application of formaldehyde before any seed is sown.

Sterilized soil should never be cultivated with contaminated tools. A separate set of hoes, rakes, and other implements should be used, and these should be dipped into formaldehyde at the time the soil is being treated. Neither should the workmen be permitted to walk over the clean beds with shoes or boots that have clinging to them untreated soil. The safest plan is to have an extra pair of old shoes that are worn only on the beds where the disinfectant has been applied. The seed should be treated before planting; the water for wetting should not be taken from a source where diseased plant material could get in; and every other precaution should be taken to keep the sterilized soil free from organisms that might prove injurious.

Steaming is the most satisfactory means of sterilization. If a steam boiler or a traction engine that will generate at least eighty pounds of pressure is available, one of the following methods may be used. A three-inch iron head-pipe long enough to reach across the width of the bed is supplied with an iron nipple for the attachment of the steam hose midway between the closed ends. On the opposite side of the pipe are one-and-one-half-inch openings, from twelve to eighteen inches apart. These openings are supplied with flanges projecting three or four inches, over which the ends of galvanized steam pipes are fitted. These latter pipes are perforated with one-fourth-inch holes on their underside at intervals of six inches thruout their entire length of twelve or sixteen feet. The whole apparatus is buried one foot under the surface of the soil, the head-pipe being placed across the end of the bed, and the perforated pipes running parallel with the length of the bed. The ground is then covered with canvas, burlap, or boards, to conserve the heat. For the treatment to be fully effective all parts of the soil to a somewhat greater depth than that which has been worked must be heated to a temperature of above 200°F. and held there for at least a few minutes.

A second method is the use of three-inch glazed drain tile laid in parallel rows, fifteen inches apart, the length of the bed and a foot below the surface of the soil. Instead of using a head-pipe, the steam pipe direct from the engine is inserted into each row of tile in succession for from one to two hours. There is an advantage in this method since the tile may be left in place thruout the year. The disadvantage is that the soil may cake about the tiles. It should be spaded and covered before steaming begins. The manure used as fertilizer should also be added before sterilizing so that the beds will not become recontaminated. For the same reason, implements should be disinfected with formaldehyde before the soil is worked.

A popular and effective method of steam sterilization is to invert over the soil a galvanized iron pan from six to ten inches in depth and of any convenient size. Live steam is passed under the pan for the length of time indicated (page 11), after which the pan is moved to an adjoining area. A drag-like arrangement with many perpendicular perforated pipes, which are jabbed down into the soil, is used occasionally, but unless a pan or some other covering as building paper is placed over the drag, the steam escapes too easily from the soil.

The same precautions should be taken regarding recontamination after the application of steam as were suggested for the formaldehyde treatment.

In the case of onion smut, the entire soil is not sterilized, but only that immediately adjacent to the seed. This is done by applying a formaldehyde solution in the furrow with the seed at the time of sowing. A solution of the desired strength is made by adding 1 pint of commercial formaldehyde to 16 gallons of water. This solution should be applied at the rate of 200 gallons to the acre.

The application may be made by means of a watering device attached to the drill. By this method the liquid is discharged in the open furrow either behind the seed or directly with it in such a manner as to prevent washing of the seed in the row. Tanks of 3-gallon capacity for this purpose can be attached readily to a seed drill. A stopcock and a tank outlet of 5/16-inch bore when opened wide, will make the desired application for an acre, the rate of flow varying somewhat with the arrangement of the tank and the size of the conducting tube used. A properly equipped drill should discharge when stationary 1 gallon of the solution every fifty seconds.

CONTAMINATED MANURE

One of the common methods of disseminating disease-producing organisms is by means of contaminated manure, or by the use of incompletely composted refuse employed as humus. When clubrooted cabbage or other crucifer is fed to sheep or cattle, millions of spores of the clubroot parasite are mixed with the manure, which may be spread over the fields or even be applied to the seedbed. If it is applied to the seedbed, the young plants are sure to become infected, but in the coolness of early spring they may show no signs of the disease. When the plants are set in the field, the infected ones will be lost, and adjoining plants later will become infected. For this reason great care should be taken in selecting the manure that goes into the seedbed. Furthermore, no cabbage or cauliflower plants should be transplanted from a bed that shows even one clubbed root.

Corn smut is not carried on the seed as so many people believe, but the spores winter over in the soil, in manure, or on diseased stalks, and germinate best in the spring when the leachings of manure are present. When cornstalks are fed to the cattle, the manure becomes contaminated with the smut, resulting in the wide dissemination of the parasite.

The dry root rot of beans first appeared in a severe form in the area where it had been customary to feed bean straw to winter lambs. Fields in which no beans had ever been grown were inoculated when the sheep manure was hauled over the farm. It would have been cheaper to have burned the diseased straw than to have permitted the root rot to become so thoroly established.

Numerous other plant parasites are disseminated occasionally with manure, so that it always is an excellent precaution to know the source of the material used as fertilizer, and to avoid any that has the slightest chance of carrying disease-producing organisms.

CULTIVATION

Plowing and cultivating the soil influences in different ways the growth of plants, and accordingly influences the growth of molds and bacteria in a similar manner. These two practices may result in reducing the weeds, in covering up diseased refuse, in making more uniform the supply of moisture, in injuring the roots of the crop, in carrying the parasite on the cultivator and operator to healthy plants, or in uncovering the parasite after it has been plowed under.

Many weeds are direct carriers of parasitic organisms and, therefore, should be eradicated. In addition they compete with the crop for moisture and nutrients, smother crops, and hinder the rapid drying of foliage, and in these ways make it easier for the causal agents of certain diseases to spread. Therefore, an important control measure is to cultivate carefully the field to destroy all the weeds, and to keep the fence rows and the roadsides closely mowed.

When the soil is plowed properly, much diseased refuse is turned under so deeply that the fungus or bacterium dies with the rotting of the old plant tissue, and never has a chance to infect new growth. It is for this reason that refuse from celery, lettuce, tomatoes, and in fact, from every crop that is not rotated, should be covered if it cannot be raked together and burned.

When the soil is wet, frequent shallow cultivations will aid it in drying, and pulverized soil is more likely to retain water during a drouth than that with large clods. For this reason cultivation tends to keep the moisture uniform, which in turn reduces injury from such diseases as black heart of celery, lettuce drop and tipburn, blossom-end rot of

tomatoes, and other similar troubles. In reducing the amount of surface water, the air next to the ground is kept drier, so that damping off of young plants is reduced. This fact is generally known by the growers who stir the topsoil frequently in the seedbed. The stirring also serves to break up threads of mycelium, like that of Botrytis in greenhouse beds, where an active fungus may grow from one plant to another. On the other hand, if the soil is plowed or cultivated when very wet, it may become puddled, or it may dry out so quickly that tipburn of cabbage and other physiological troubles will be increased.

As soon as a crop is observed to have root rot, it is well to stop cultivating, for when the lower feeding roots are killed, the plant frequently puts out new roots near the surface of the soil and, if there is enough rain, grows even tho the taproot is almost completely decayed. This is true especially of the bean. If, however, cultivation is continued, the new feeding roots may be cut off and the plant will die.

Every grower has heard the remark that beans should not be cultivated while the plants are wet with dew or rain. The reason is that the spores of the anthracnose fungus are exuded in a gelatinous covering which dissolves only in the presence of water. The free spores cling to tools or clothing and are disseminated to all parts of the field. The same thing is true, tho to a lesser extent, of bacterial blight of beans, as well as the leaf blights of tomato and of celery.

Celery growers have learned to spray before rather than after cultivating, for in a field where celery has been grown the previous year, much of the diseased material has been plowed under. The cultivator drags some of this refuse to the surface where the fungus fruits and is then ready to cause infection. But if the leaves are sprayed thoroly just before cultivation, the plants are protected. Applications after cultivation may fail to halt the entrance of the parasite. Probably the same condition prevails in the case of tomato and melon leaf spots.

SPRAYING OR DUSTING

As soon as control measures are mentioned, one is reminded of spraying or dusting, for it is one of the most common practices among growers. No gardener can afford to be without a good sprayer, a hand duster, and the materials to apply as a spray and as a dust. The dust may be bought ready mixed, but usually it is more desirable to prepare the spray at home.

Bordeaux mixture is made by combining a dilute solution of copper sulfate (blue vitriol) with a dilute milk of lime. Mixtures of various strengths may be prepared by using different amounts of copper sulfate and lime to a given amount of water. For most vegetable spraying the 4–4–50 strength is recommended, and is made of 4 pounds of copper

sulfate and 4 pounds of lime to 50 gallons of water; or in very small amounts, 4 ounces of copper sulfate, 4 ounces of lime, and 12 quarts of water. The procedure for making bordeaux mixture is as follows:

A stock solution of copper sulfate may be made in a barrel by dissolving 50 pounds of copper sulfate in 50 gallons of water. A gallon of this solution thus contains 1 pound of copper sulfate. In case large quantities of stock solution are needed, 2 pounds of copper sulfate may be dissolved to 1 gallon of water. If the crystals are placed in a gunny sack and suspended just beneath the surface of the water, they will dissolve in the course of three or four hours.

A stock mixture of lime may be made by placing a bushel of good stone lime in a barrel, and slaking it by the gradual addition of water. Care must be taken not to "drown" the lime. When the lime has become pulverized by the slaking, water is added to make a paste, after which enough more water is added to make 50 gallons. This mixture should not be allowed to dry out. Hydrated lime, which is already slaked, may be used in place of stone lime, but air-slaked lime should never be used.

The sprayer is filled three-fourths full of water. If a 5–5–50 solution is desired, 5 gallons of copper-sulfate stock solution are added to this water for every 50 gallons of mixture to be made. The solution requires stirring until it is well diluted, after which 5 gallons of the stock mixture of milk of lime is added to each 50 gallons of mixture. The lime water should be run thru a strainer in order to prevent the large particles of lime from getting into the sprayer tank. The dilute copper-sulfate solution in the sprayer tank should be stirred constantly as the milk of lime is being added to it. The sky-blue bordeaux mixture will result. Enough water to make the required amount of mixture is then added.

The mixture should be made immediately before using, as it deteriorates rapidly when standing. The stock solutions, however, may be stored indefinitely. Only wooden or earthen vessels should be used as containers for the copper-sulfate solution and the bordeaux mixture, for these substances corrode iron or tin.

If copper-lime dust is applied, a large enough amount should be used so that both sides of the leaves and the stems can be well covered. It is necessary to go on both sides of the row with a hand duster when the plants are large. From 20 to 50 pounds of dust are necessary for an acre of vegetables, depending upon the size of the plants. It is best to dust while the plants are wet with dew, for if the lime is exposed on the dry leaf surface it quickly changes to the ordinary raw limestone form, which does not mix with the copper to make a fungicide. Some growers find it more convenient to dust in the late evening, while others would rather do it in the early morning.

When spraying, the most important precaution is that of having a high pressure. When a hand sprayer is pumped up with all the pressure it will bear, and the nozzles are so directed that all parts of the foliage are covered, fairly good results will be obtained. But it is better to have a traction or engine sprayer in which the pressure can be kept to more than two hundred pounds. In order to keep up the pressure, the small discs in the nozzles should be changed frequently, so that the holes will not be worn large. In addition to pressure, the nozzles should be numerous and so directed that all parts of the plant are covered. For celery and tomatoes, three nozzles usually are sufficient even for full-grown plants, but four or five are not too many for melons that are vining, unless the spraying is done by a lead hose, with a man to direct each nozzle by hand.

The spraying always should be done before rains, and usually before cultivation. If the bordeaux mixture is put on in a fine mist, it dries almost instantly, and therefore will not be washed off. A small amount of arsenate of lead or arsenate of lime added to the spray not only aids in repelling insects, but seems to help as a fungicide.

Crops that may be sprayed or dusted	Strength of bordeaux mixture	Time of first application	Number of times to spray or dust	Diseases
Beans (lima)	4–4–50	Before disease appears	3–5	Downy mildew
Beets	4–4–50	When plants are up	3–5	Leaf spot
Carrots	4–4–50	Before disease appears	3–5	Leaf blight
Celery	5–5–50	Three or more times in seedbed	5 in field	Leaf blights
Cucumbers	4–4–50	As soon as plants are up	5–7	Leaf spots, anthracnose, scab
Cantaloupe	3–6–50	As soon as plants are up	5–7	Same as for cucumber, bacterial soft rot
Eggplant	4–4–50	Before disease appears	3–5	Phomopsis blight
Lettuce (for seed)	4–4–50	Near flowering time	2–3	Gray mold rot
Onion (for seed)	4–4–50	Near flowering time	3–5	Macrosporium black mold
Pepper	4–4–50	When plants are up	3–5	Various leaf and pod spots, anthracnose
Rhubarb	4–4–50	After regular harvest	2–3	Various leaf spots
Salsify	4–4–50	When plants are up	3–5	White rust
Tomato	5–5–50	Three or more times in seedbed	5–7	Leaf spots and blight, fruit rots

ROGUING AND THE DESTRUCTION OF DISEASED PLANTS

In controlling animal diseases, the individual with a contagious disease is isolated so that the others will not become infected. The same method can be applied in combating plant diseases, altho it usually is more difficult because of the large number of individual plants involved. Isolation of healthy plants is an important means of reducing the amount of degeneration diseases, such as leaf roll and mosaic, in a given stock. The men who grow potatoes for certification could not long remain in the business if they did not isolate their seed plots and painstakingly rogue out, that is, pull up and remove, each diseased plant as soon as it appears. Many other vegetables are affected by mosaic, including beans, celery, cucumbers, spinach, muskmelons, lettuce, peppers, and tomatoes; but it is doubtful whether in any of these cases one would be justified in trying to remove the diseased plants. The bean and lettuce mosaics are carried in the seed so that the best control measure under those circumstances is to procure or grow clean seed. If a seed plot of lettuce or beans were isolated, roguing might be practiced in order to have a healthy strain for future planting. Not enough is known of celery mosaic to make suggestions regarding its control. The mosaic on cucumbers, muskmelons, and on tomatoes is not carried in the seed, but is transmitted thru perennial weed hosts (page 4) which should be eradicated. Roguing the first few diseased plants also may be a help, for these serve as a source of the virus which insects spread to healthy vines. Too much roguing late in the season, however, merely reduces the yield of the crop, without producing any corresponding reduction in the number of diseased individuals.

Roguing, or cutting out, smutted stalks in a field of sweet corn is an excellent precaution. If smut has been severe, the field should be inspected three or four times in the season, and all the smut balls should be removed before they are mature enough to burst. Since this green material cannot be burned, it is well to carry it from the field in a paper-lined basket or a paper bag and bury it deeply enough so that the spores cannot reach the surface. One year of cutting out affected stalks is not enough to control corn smut, but each year's work will help in reducing it. If close neighbors practice the same sanitation, the smut can be controlled much more satisfactorily.

In the case of bacterial wilt of cucumbers and muskmelons, the vines that show even the slightest wilting should be pulled up at once and removed from the field, for the beetles feed on the wilting plants and then carry the inoculum to adjoining healthy ones. The pickers, too, when breaking off the pickles, smear the bacteria on their hands, and carry them to neighboring plants.

In the greenhouse it has been found that the spread of lettuce drop is hindered if affected plants are removed carefully with a wide trowel as soon as they appear, and the soil about the hole is disinfected with a copper-sulfate solution (1 pound in 5 gallons of water). This, of course, is practicable only when a small proportion of the crop is diseased, and never can replace complete sterilization of the beds before the crop is planted.

INSECT ERADICATION

Mosaic diseases are transmitted by means of sucking insects, among which the aphid is the most common carrier of the virus. The leaf hopper not only helps in spreading leaf roll but on potatoes may cause the severe injury known as "hopperburn." The mosaic on cucumbers and muskmelons is transmitted also by the cucumber beetles. Leaf miners (two kinds) and the carrot rust fly cause wounds thru which the soft-rot organism of vegetables enters celery plants. There are numerous other cases where insects cause injury and diseases follow the wounds, or where the spores of parasitic fungi are carried on the legs or feeding parts of the pest and thus are disseminated over long distances. One of the most interesting is that of the cucumber beetle, which in the fall feeds on vines affected with wilt, and the living bacteria enter its digestive tract. These organisms remain alive while the beetle hibernates thru the winter, and then in the spring, are deposited on the young leaves of the cucumber or muskmelon in the droppings of the insect. So far as is known this is the only means the parasite has of overwintering, so that if the insects are killed or repelled there is no other chance for early infection.

The most practical means of killing aphids is by spraying with nicotine (1 pint in 100 gallons of spray) or dusting with a strong nicotine dust. Since they are on the underside of the leaf, the spray or dust must be so directed that it will hit them in that position. A handy tool for this work is a hand sprayer or duster with an extension rod that will touch the ground when the operator is standing upright, and with the end of the rod curved upward at a forty-five-degree angle from the soil. The nicotine may be placed directly in the bordeaux mixture, and the application will then serve a double purpose.

Leafhoppers and cucumber beetles are difficult to hit because of their activity. Entomologists suggest the use of a large funnel on the end of the duster nozzle. The funnel is set over the cucumber and muskmelon plants when they are small and the nicotine dust is forced into it. The insects will be unable to escape the enclosed fumes. Spraying the vines with bordeaux mixture to which arsenate has been added, or dusting with

copper-lime-arsenate dust each week, beginning as soon as the plants are up, has proved satisfactory, as the plants will then be protected directly against the wilt bacterium, which is not true when nicotine is used alone.

DESTROYING DISEASED REFUSE

Those who grow lettuce on muck soil usually harvest only the best heads and leave the remainder on the soil to become decayed by means of bottom rot, drop, and gray mold rot. This really increases the inocula of the parasites a thousand fold, so that the lettuce crop planted on the same soil later almost invariably becomes infected. A few men have tried the plan of removing all the plants as fast as the harvest is completed, and hauling away the refuse, which is dumped on a compost heap. Altho the labor involved in such refuse eradication is considerable, it has been found to pay.

Celery growers, for the most part, trim off the undesirable part of each stalk, and leave the waste material in the field. Since this waste consists mostly of diseased leaves and petioles, an immense amount of fungous or bacterial inoculum is left to menace the celery crop the following year. If it is plowed under, a certain amount will be pulled up again by the cultivator and will prove destructive to the growing plants.

Frequently cabbage growers find that their kraut cabbage is too cheap to permit cutting, so they harvest a few of the best heads and leave the remainder to rot in the field. These old plants are especially susceptible to Sclerotinia which also causes the drop of lettuce. Millions of sclerotia are formed in such a field, and are ready to produce plenty of inoculum to infect the next year's crop. If this extra material could be fed to cattle or sheep, it would be desirable from a disease-control standpoint.

In a similar way, diseased cucumbers, muskmelons, watermelons, and tomatoes are left in the field after harvest, when they should be buried or destroyed in some other manner.

HARVESTING AND CRATING

It would seem that after a gardener has taken all the trouble needed for growing a healthy crop, he would be most willing to practice every precaution in harvesting and handling the crop, but this is not always true. Many vegetables are harvested to early or too late, are bruised in handling, the good and bad are thrown together, or are placed into too tight containers, all of which aid rot-producing fungi to gain an entrance and later cause loss in transportation or storage.

The onion is the one crop, whose keeping qualities are greatly influenced by the handling the crop receives before it goes into storage. Only the healthy, mature onions should be placed in crates. Onions should be dried thoroly before they are put away for the winter. If the sunshine is not sufficient to cause fast enough drying, artificial heat has proved economical in saving the crop. The bulbs are laid in shallow trays, which are stacked loosely in a drying flue. Warm air is introduced at the bottom of the stack and withdrawn at the top of the flue. The diseases partly controlled by this drying are neck rot, smudge, and soft rot.

One of the most common errors in harvesting is that of handling the fruits or roots roughly. They are pitched from the plant to a deep, stiff crate with no precautions against bruising, or are rolled over a chute, or dropped on a cement or wooden floor without considering the injury. Such fruit as cucumbers and tomatoes should be picked and laid carefully into a soft smooth-surfaced basket. If the vegetable can be handled without a bruise, the healthy epidermis is a safe-guard against many of the fungi and bacteria that are present in the soil, air, or on the containers, and thus will remain whole in storage or shipment.

STORAGE AND TRANSPORTATION

The storage house and containers should be cleaned well each autumn, and then disinfected by scrubbing the floors and walls with a blue-vitriol solution (1 pound in 5 gallons of water) or a corrosive-sublimate solution (1 ounce in 7.5 gallons of water) and dipping the crates into the same solution.

Much attention should be paid to the moisture and the temperature in the storage house. Most root crops demand a rather humid condition, and a temperature near 32° F. Potatoes, however, keep best at 37° F. Squashes and pumpkins, on the other hand, require a fairly dry air and a temperature of approximately 55° F. For the dry storage house, the door should be kept tightly closed during rains, and opened only when the air outside is fairly dry. A cellar that is too dry, however, may shrivel the stored vegetables. For this reason it is recommended that during the early fall and until cold weather appears, the doors and windows should be closed during the day and opened at night when the humidity of the out-door air is high and the temperature is low. Naturally, the temperature is watched very closely during the winter and never permitted to go below the freezing point. As a further precaution against freezing, if the walls are of stone or concrete, an inner wall of boards is constructed so that the vegetables are not left in contact with the cold stone, where they might become chilled.

If the storage house is too dry, a tub of water left standing in the middle of the floor helps to increase the dampness. In an artificially cooled room the overhead cooling pipes frequently drip water on baskets or crates below and thereby aid rot-producing molds to gain an entrance into the stored material. Such pipes should have a tin gutter suspended below them to catch the drip.

As roots and fruits are living tissue, they need plenty of oxygen, therefore, they should never be placed into deep heaps, or stacked too closely in crates.

Many rot-producing organisms spread from one host plant to another in the bin. This is true especially of soft rot and black rot of carrots, and of gray mold rot of witloof chicory. To avoid this possibility, the roots may be stored in straw, old leaves, or sand. A mixture of sand and leaves retains the moisture well, and keeps the roots from shrinking.

Onions should be dried thoroly before being placed in storage. They may be placed in shallow trays and held at a temperature of 90° to 120° F. for forty-eight to seventy-two hours if an artificial drying method is available, after which they are stored at about 32° F. If there is danger of their becoming too wet while in storage, the ventilators should be opened and air circulation permitted.

Pink rot of celery is caused by a fungus that will grow at temperatures as low as freezing. But celery kept at about 31° F. remains relatively free from this disease which causes so much damage each winter.

Cabbage when put into storage should have all the leaves with Alternaria leaf spot removed, for if any of these spots remain, they offer an entrance into the healthy tissue of the soft-rot bacterium.

In shipping vegetables, the same precautions should be taken as were suggested for the storage house. Many that are shipped in refrigerator cars are placed there after they have stood in the hot sun, so that they do not cool quickly. During this high temperature they may become infected and then appear on the market in a very poor condition. Frequently, too, vegetables are placed in poor containers for shipment. When the containers are crushed, the vegetables are bruised and are then easily infected by molds that could not enter a healthy plant part.

TEMPERATURE AND MOISTURE IN THE GREENHOUSE

The greenhouse conditions can be governed more readily than those in the field, so that it often is possible to control diseases by changing the moisture and temperature of the air and the soil. It is true that some greenhouses are so poorly constructed that air humidity is almost impossible to govern and sunlight is excluded by walls or posts. In such

houses damping off of seedlings, Cladosporium leaf mold of tomatoes, gray mold rot and anthracnose of lettuce, and other vegetable diseases, usually are common and destructive. Where unobstructed light is available, and the roof of the greenhouse is high enough to permit good ventilation, there should be little trouble with parasites that grow only when abundant moisture is present.

Most of the leaf and fruit spots of vegetables are increased when the plants are watered frequently by means of a spray. The wetting of the leaves can be avoided by watering the soil directly, or even by surface irrigation instead of over-head sprinkling. So frequently, too, the steam pipes drip water, and this adds to the moisture on the leaves. All pipes should be inspected carefully, and faucets should not be permitted to leak.

Diseases in the greenhouse may be controlled by temperature in two ways. When it is high enough and there is ventilation, it helps to dry the air and thus reduces the amount of water on the foliage. This helps to combat such troubles as Cladosporium leaf mold on tomatoes and scab of cucumbers. The plant parasites also may be susceptible to temperature directly. For instance, downy mildew and anthracnose of lettuce do not cause serious injury if the night temperatures of the house are run three or four degrees higher than ordinarily are recommended for this crop. In the case of gray mold rot just the opposite is true. The night temperatures should be run as low as growth of the lettuce will permit.

GREENHOUSE FUMIGATION

Several of the greenhouse diseases of vegetables are caused by fungi that are more susceptible to sulfur injury than to copper. Therefore, sulfur fumigation before the plants are set into the house has proved desirable. After all living plants have been removed, the greenhouse is closed tightly. An iron kettle or other container is then set in a pan of water, which supplies the necessary moisture. Five pounds of sulfur for each 1000 cubic feet of space to be fumigated are placed in the kettle. To start the burning of the sulfur a hollow is made in the top of the pile, into which a little alcohol is poured. This is lighted and it lights the sulfur. The house is kept closed for at least twenty-four hours, after which it is well aired. Fumigation cannot take place while plants are growing in the greenhouse.

The sulfur fumigator is meant particularly for Cladosporium leaf mold of tomatoes and Cladosporium scab of cucumbers, and powdery mildews of vegetables. It may also kill insects that winter over in the greenhouse and that transmit diseases of plants.

EXCLUSION

Altho a seasonal program for the control of plant diseases is excellent, there is one practice which is even better, and that is keeping the disease out of the country, or the State, or at least off the farm. There are certain diseases like black wart of potato, white rot of onion, Cercospora leaf spot of onion, and other troubles that are not found in this State. It may be that the climate is unfavorable for the organisms that cause these troubles, so that they would not produce injury even if they were imported. But no chances should be taken, for too many diseases already have been introduced with disastrous results. Among these are asparagus rust, cabbage clubroot and blackleg, and late blight of potatoes.

There are still many individual farms on which certain destructive diseases have not occurred. On such a farm the grower should use every means available to exclude any organisms that are not present. Among these are the ones that cause dry root rot of beans, crown gall of beets, celery yellows, blackleg, black rot and clubroot of cabbage; mosaic, angular leaf spot, and scab of cucumbers and muskmelons; Verticillium wilt of eggplant; onion smut; and tomato bacterial spot. The first thing the grower must do to effect such exclusion is to become familiar with the symptoms of the disease, its distribution, and the methods by which the organism is disseminated. When he once has these facts, he has a working knowledge for planning the exclusion of the parasite in which he is interested.

INDEX TO CONTROL MEASURES

Key number to control measures	Control measure	Asparagus	Beans					
		Rust	Anthracnose	Bacterial blight	Mosaic	Dry root rot	Rust	Downy mildew (lima)
1	Rotation of crops		X	X		X		X
2	Eradication of weeds							
3	Drainage		X	X		XX		X
4	Applications of fertilizers and soil amendments		XX	X	XX	XX		X
5	Selection or purchase of seed	X	XX		XX		X	
6	Resistant varieties or strains			X				
7	Seed treatment							
8	Time of planting							
9	Seedbed treatment and soil sterilization							
10	Contaminated manure		XX	XX		XX		
11	Cultivation		XX	XX		XX		X
12	Spraying or dusting				X			
13	Roguing and the destruction of diseased plants							X
14	Insect eradication							
15	Destroying diseased refuse		X	X		X		X
16	Harvesting and crating							
17	Storage and transportation							
18	Temperature and moisture in the greenhouse							
19	Greenhouse fumigation					X		
20	Exclusion							

INDEX TO CONTROL MEASURES (*continued*)

Key number to control measures	Beets		Carrots			Witloof chicory	Celery					Sweet corn		Cabbage, cauliflower, and other crucifers								
	Cercospora leaf spot	Crown gall	Common scab	Bacterial soft rot	Alternaria black rot	Leaf blights	Gray mold rot	Late blight	Early blight	Bacterial blight	Yellows	Pink rot	Smut	Bacterial wilt	Blackleg	Black rot	Clubroot	Alternaria leaf spot	Wire stem	Peppery leaf spot	Sclerotinia rot	Malnutrition
1	X	X	X	XXX	X	X		X	X	X	X	X	X	X	XXX	XXX	XXXX	XXX	X	X	X	XX
2								X	X	X		X		XX	X	X			X			
3			X	XXX											X	X			X	X		
4																						
5											X											
6																						
7	X														X	X						
8																						
9								X	X	X			X		XX	XX	XX		X	X	X	
10								XX	XX	XX												
11	X					X		XX	XX	XX												
12													X									
13																						
14	X	X		XXX	XXX	X		X	X	X			X	X	X	X	X	XXX				
15							XX					XXX										
16																						
17																						
18																						
19											X									X		
20	X	X													X	X	X			X		

INDEX TO CONTROL MEASURES (*continued*)

Key number to control measures	Cucumbers, muskmelons and other cucurbits								Eggplant	Lettuce										
	Bacterial wilt	Downy mildew	Mosaic	Anthracnose	Angular leaf spot	Macrosporium blight	Scab	Powdery mildew	Phomopsis blight	Verticillium wilt	Drop	Bottom rot	Gray mold rot	Anthracnose	Downy mildew	Stunt	Tipburn	Mosaic	Yellows	Rabbit-ear
1	X		X	X	X	X	X	X	X	X	X	X	X	X	XX	X?			X	
2		X									X	XX	X	X		X	X			
3																				
4																				
5			X						X						X			X		
6																				
7				X	X		X		X											
8												X	X			X	X			
9									X	X	X									
10																				
11											X		Seed plants		X					
12	X	X	X	X	X	X	X	X	X											
13	X		X	X							X									
14	X		X								X	X	X							
15	X								X											
16	X																			
17														X						
18								X												
19			X				X													
20									X											

INDEX TO CONTROL MEASURES (*concluded*)

Key number to control measures	Onion: Smut	Onion: Downy mildew	Onion: Neck rot	Onion: Smudge	Onion: Pink rot	Onion: Macrosporium blight	Onion: Black mold	Peas: Ascochyta blight	Peas: Root rots	Peppers: Damping off	Salsify: White rust	Spinach: Downy mildew	Spinach: Blight	Tomato: Bacterial spot	Tomato: Septoria leaf-spot	Tomato: Macrosporium blight	Tomato: Leaf mold	Tomato: Mosaic	Tomato: Damping off	Tomato: Streak	Tomato: Fusarium wilt	Tomato: Blossom-end rot	Tomato: Grand Rapids disease
1		X		X	X	X		X	X	X	X	X		X	X	X		X			X		X
2		X							X	X		X			X	X						X	
3		X										X								X			
4		X			X Sets																	X	
5	Use of sets	X Sets			X																		
6				X				X	X	X			X	X		X		X	X		X		X
7										X			X	X	X	X		X	X		X		
8	X			X			X			X					X	X			X				
9										X						X							
10										X		X					X	X				X	
11		X								X		X		X	X	X	X					X	
12						Seed plants				X	X												
13									Shallow planting														
14		X				X		X		X	X			X	X	X	X	X	X				
15																							
16			X	X			X																
17			X	X															X				
18							X			X							X						
19																	X				X		
20	X													X									

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